Behaviour of Large FRP Ties Externally Bonded on RC Members with and without FRP Anchors

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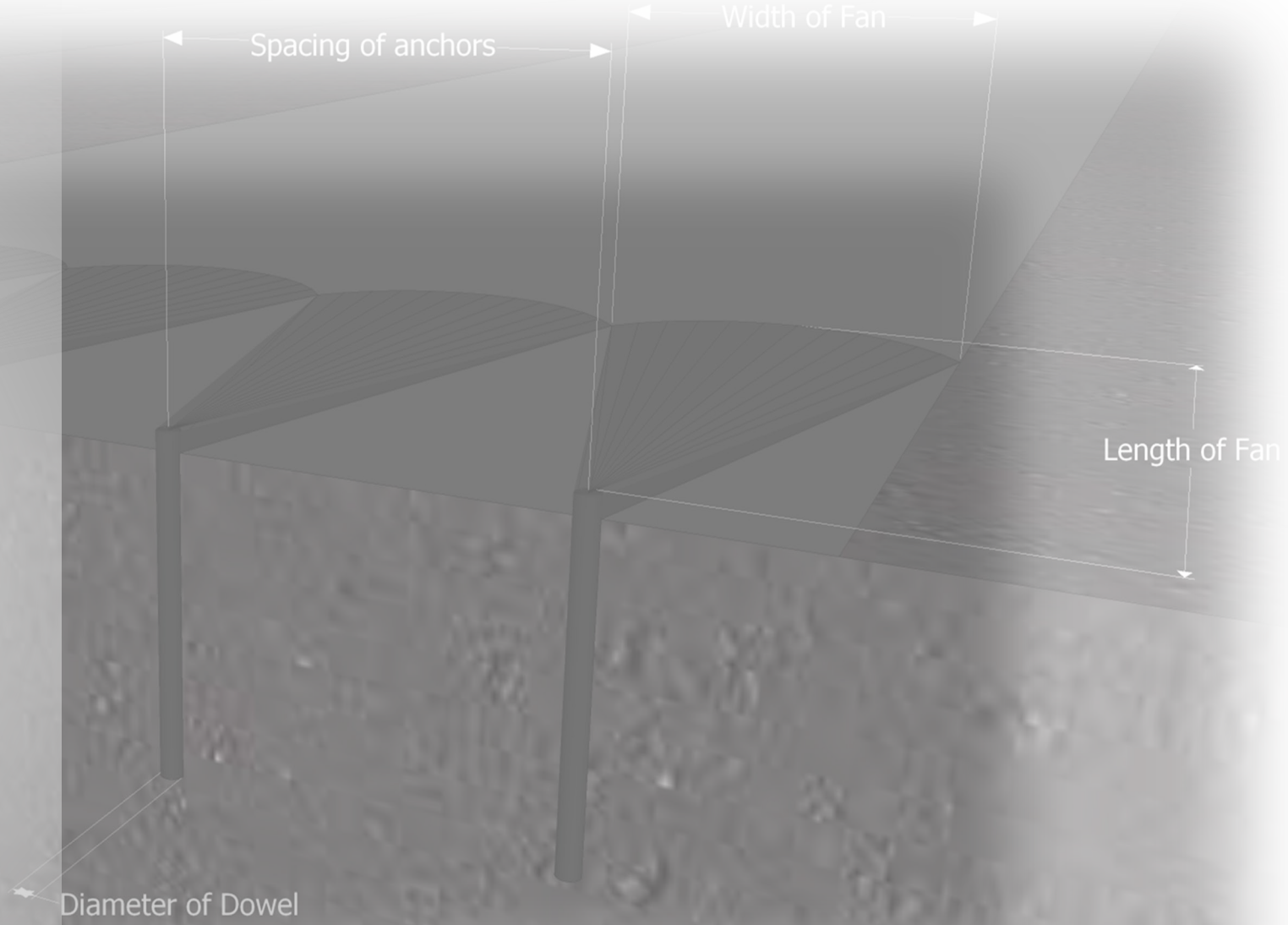

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Motivations

- **Weak tension capacity of concrete diaphragms**

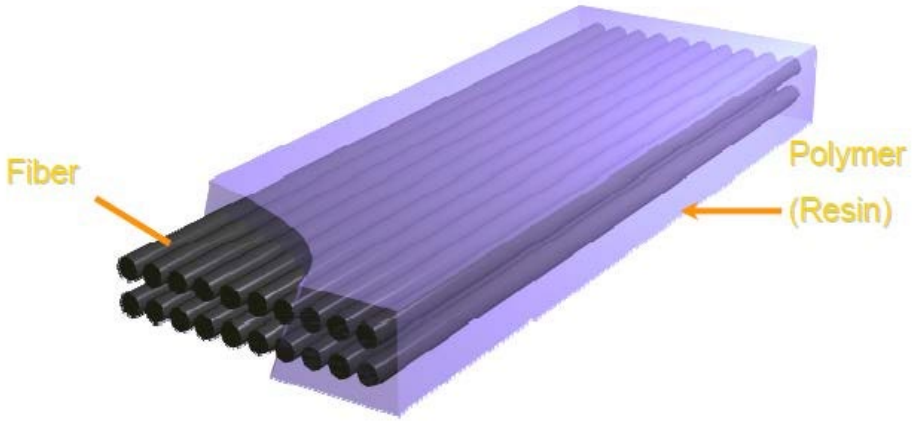
(a) Collapsed floor unit in corner of ground floor

(b) Damage in corners of floor diaphragm

Fig. 1 Damage happens to the floor diaphragm after the Kaikoura earthquake ***(Henry et al., 2017)***

Motivations (*Fibre Reinforced Polymer*)

- **FRP as strengthening materials for RC Structures**



(a) Unidirectional (Carbons Fibre Reinforced Polymer) CFRP strip

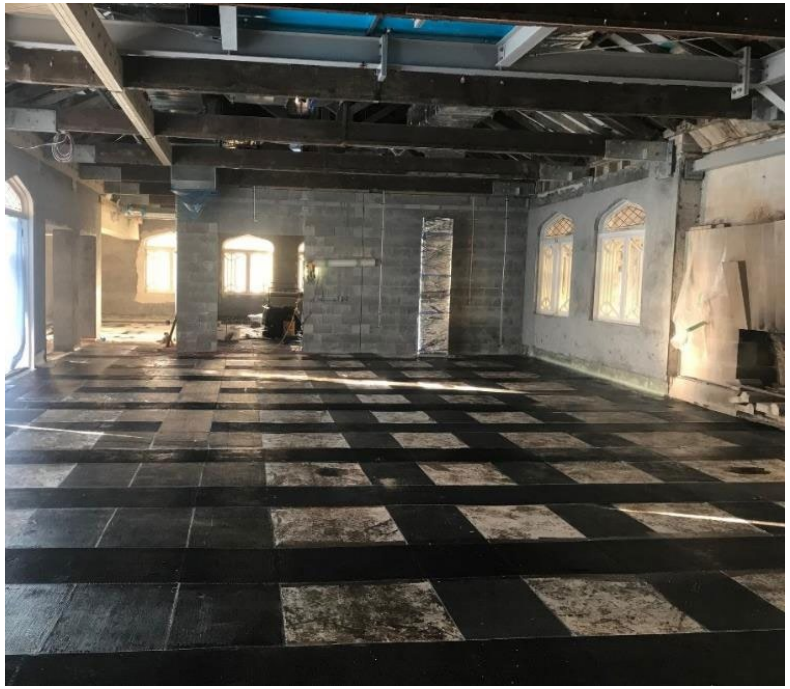
(b) CFRP strengthening application

Fig. 2 Typical of FRP and its mechanical properties ***(Galal et al., 2021)***

Case study *(del Rey Castillo et al., 2019)*

- **Concrete diaphragms strengthened by FRP with strut and tie method**

(a) The floor before FRP installation



(b) The floor after FRP installation

Fig. 3 State of the floor from the Project ***(del Rey Castillo et al., 2019-a)***

Case study *(A heritage building in Auckland)*

- **Concrete diaphragms strengthened by FRP with strut and tie method**

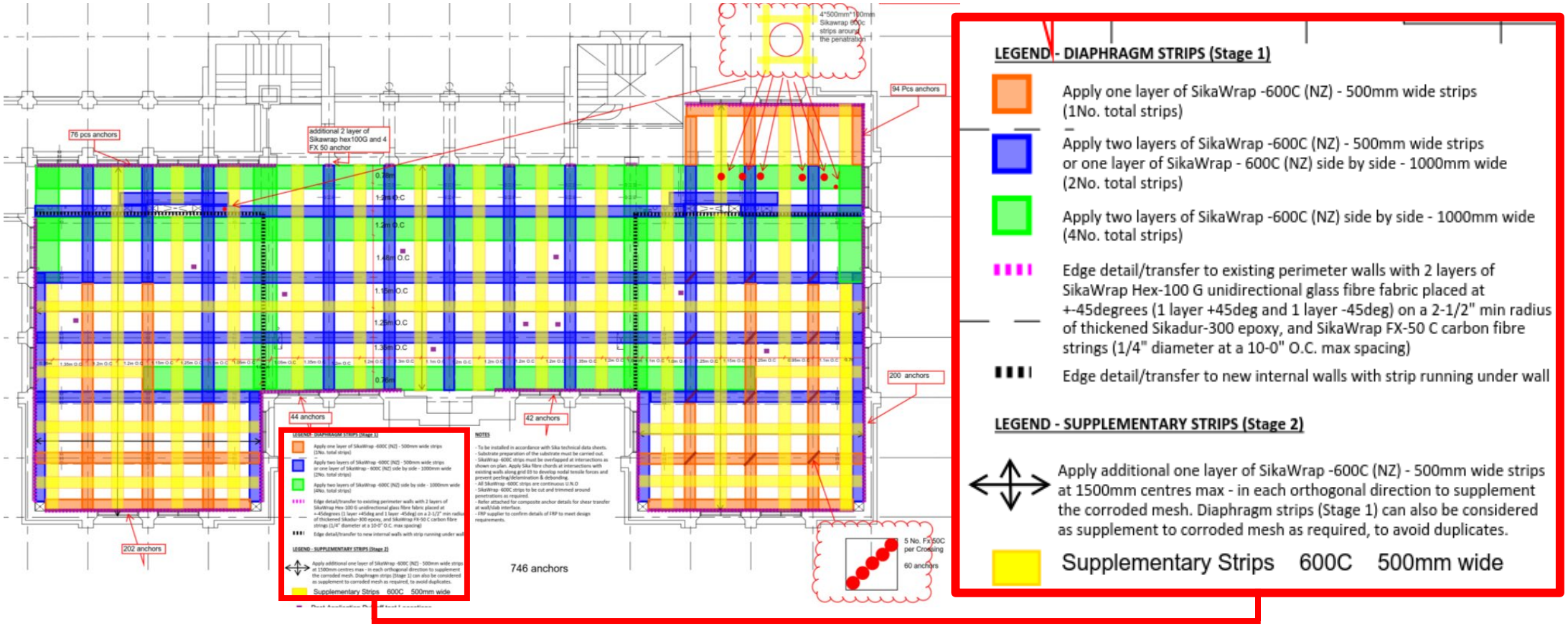


Fig. 4 Floor plan and FRP configuration ***(del Rey Castillo et al., 2019-a)***

Design of fibre anchor (*Rupture*)

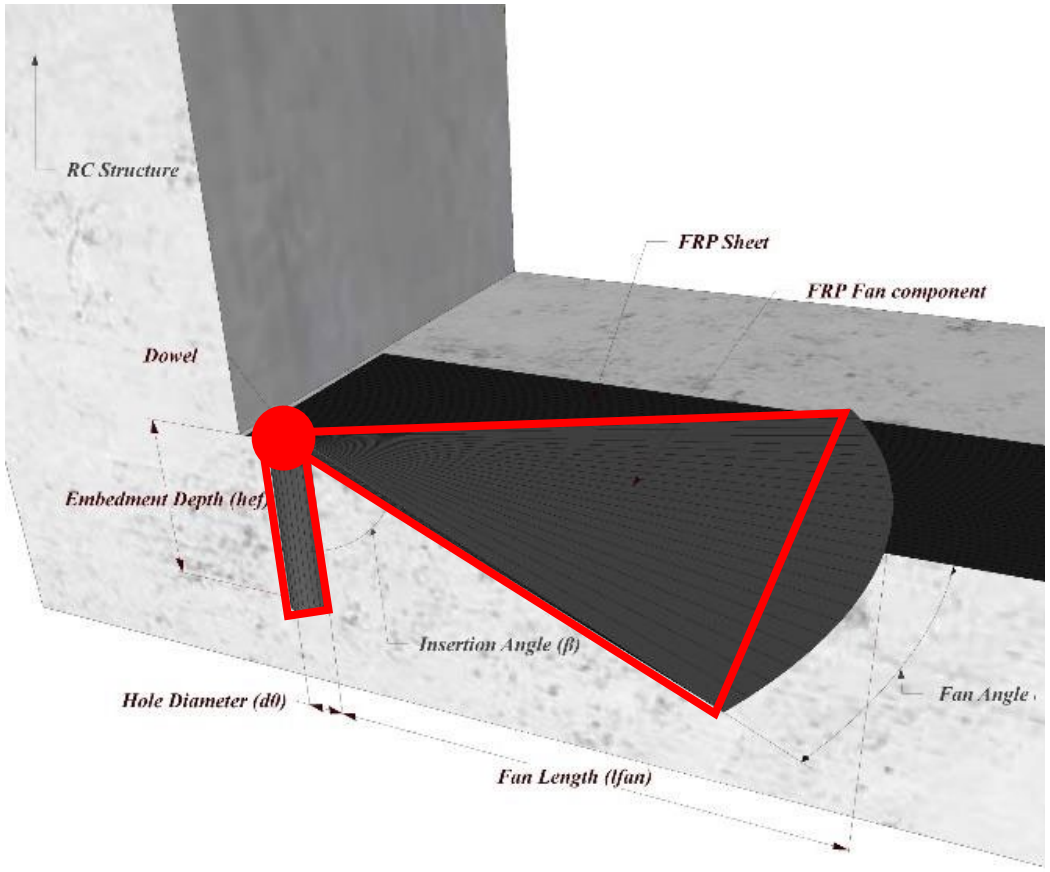


Fig. 5 Attributes of FRP bent anchor

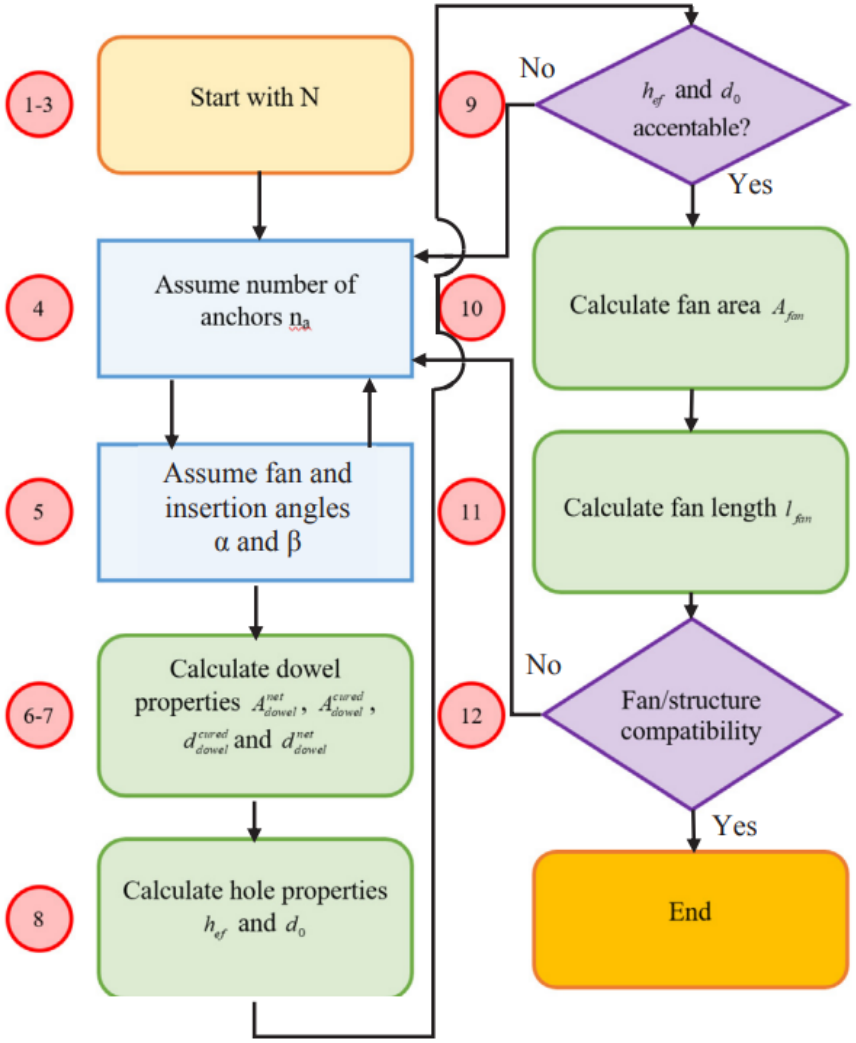


Fig. 6 FRP Anchor design flowchart ***(del Rey Castillo et al., 2019-b)***

Potential variables (*2145/3500 tests from 67/120 research works*)

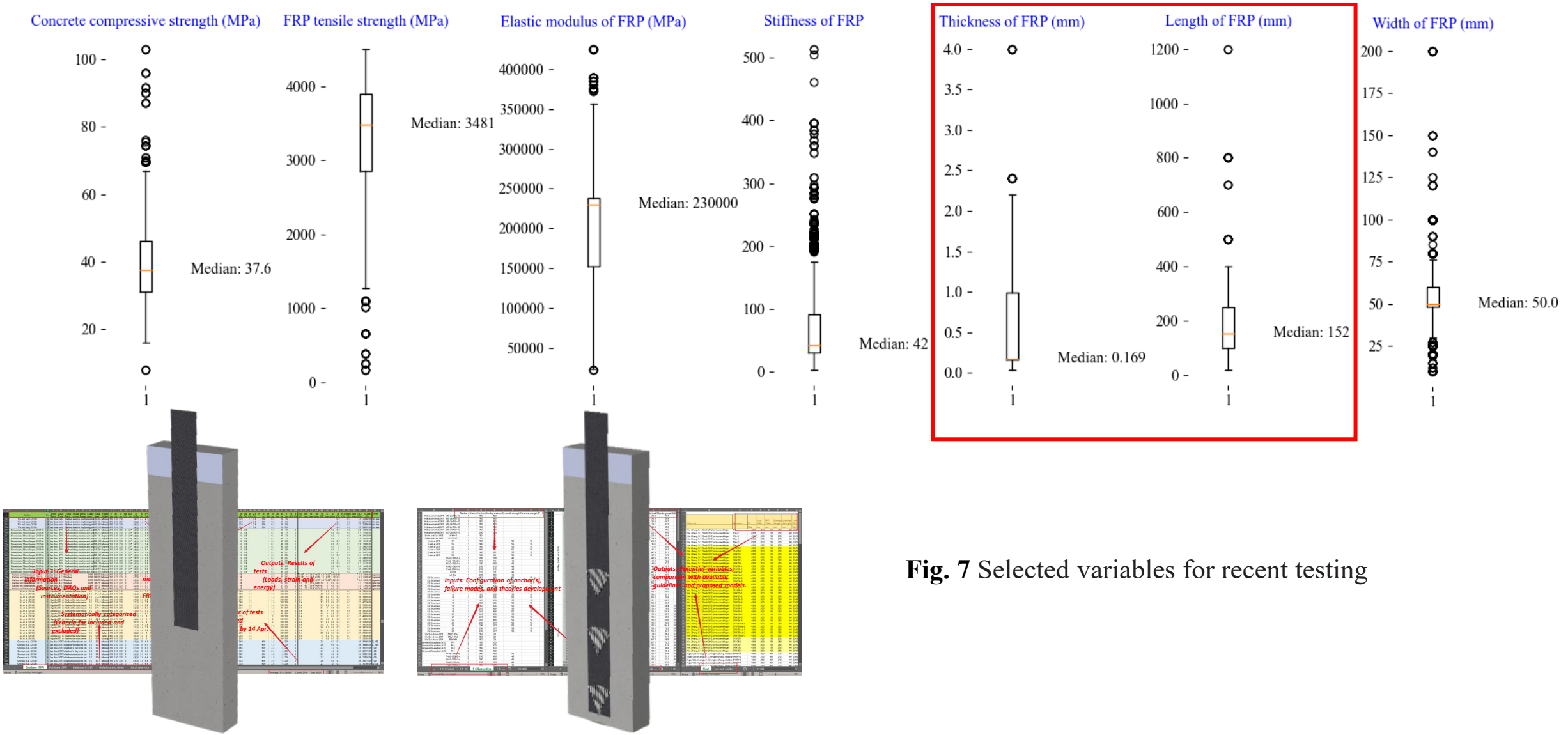


Fig. 7 Selected variables for recent testing

Cleaned published research (*1448/1993 tests from 42/66 research works*)

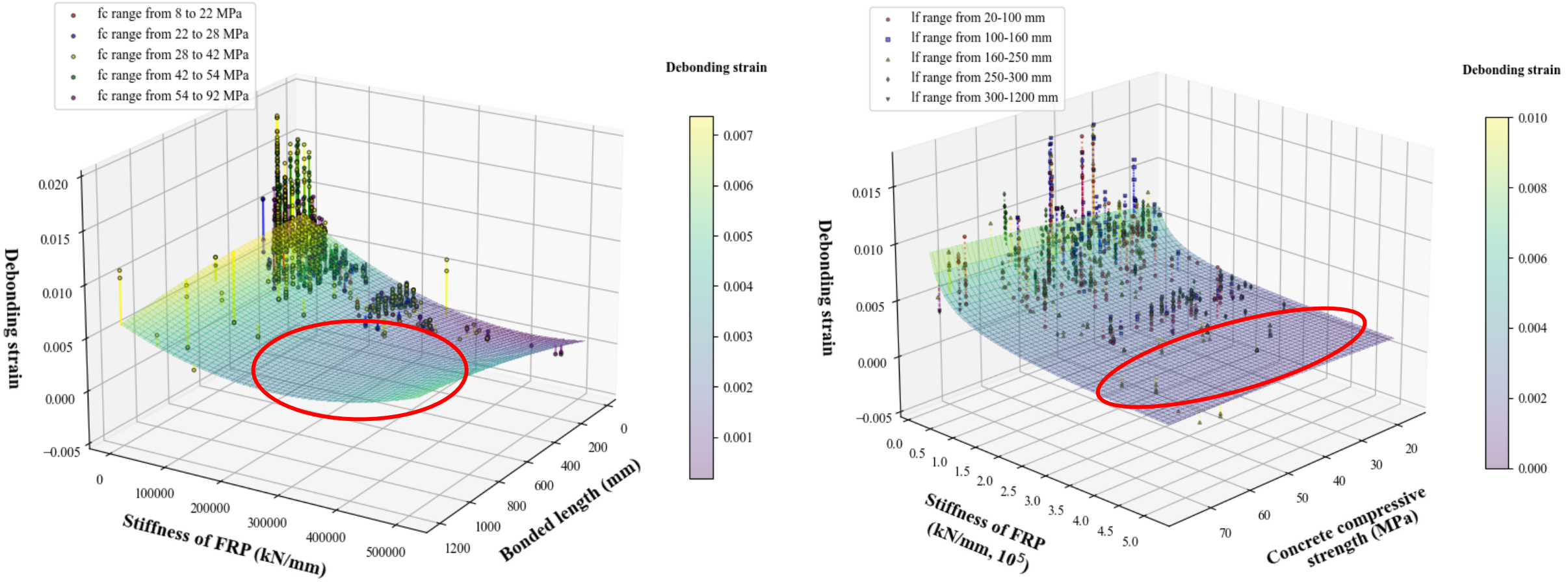


Fig. 8 Relationship of debonding strain and f_c, l_f and k_f (3D)

Considered variables (*Research gaps for unanchored EBR system*)

	Published research	Recent tests (27th Mar to 7th Apr)
Concrete compressive strength (f_c)	1500-10000 psi (10-70 MPa)	2500-5000 psi (17.2 to 34.5 MPa)
Bonded length (l_f)	< 20” (500 mm)	12” to 42” (300 to 1000 mm)
Stiffness of FRP (k_f) Elastic modulus (E_f) times total thickness (t_f)	1 or 2 layers of 11 oz (0.5-1 mm)	1 of 11 oz to 3 of 44 oz (0.5-2 mm)
Number of tests	2145 (1448)	24 + 36

(Hosseini et al., 2021)

Recent tests (*24 unpublished R&D, 36 unanchored tests and 24 anchored tests*)

Unanchored test matrix

Stiffness \ Length of FRP ties	12 in.	24 in.	36 in.
1 CSS-CUCF 11 *1 layer	1	1	1
2 CSS-CUCF 11 *2 layers	1	1	1
3 CSS-CUCF 11 *3 layers	1	1	1
4 CSS-CUCF 11 *4 layers	1	1	1

Anchored test matrix

Arrangement \ Diameter of Dowel	1/2 in.	3/4 in.	1 in.
1 Fan length of anchor with 8 in. at 42''	1	1	1
2 Fan length of anchor with 16 in. at 42''	1	1	1
3 Two anchors L_{fan} with 12, o.c. 24''	1	1	1
4 Two anchors L_{fan} with 12, o.c. 12''	1	1	1

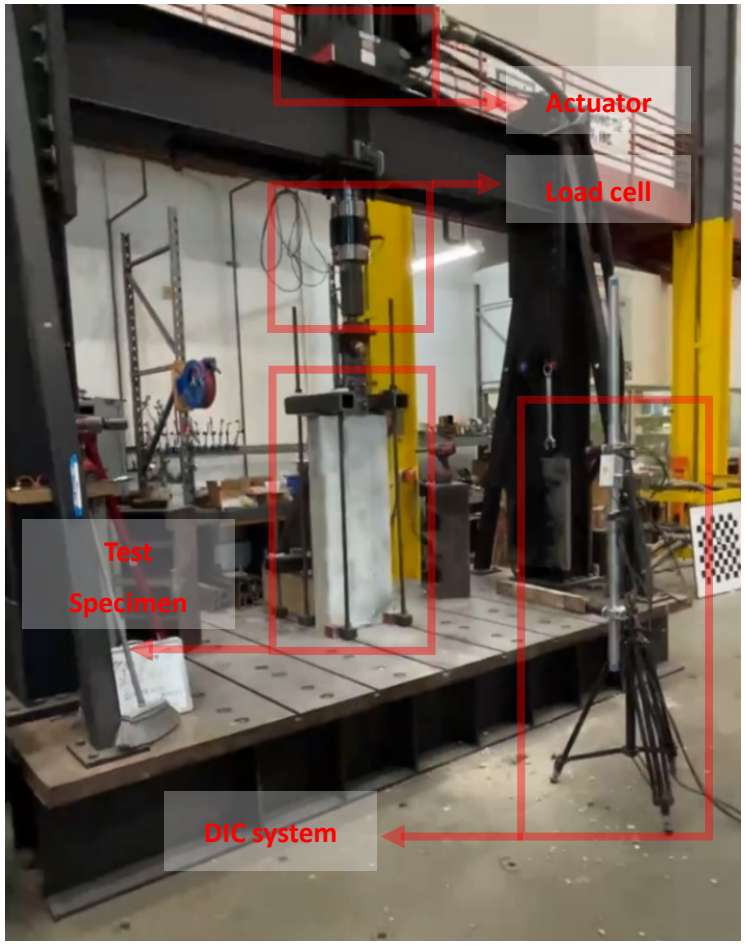


Fig. 9 Testing set-up

Recent tests (*36 unanchored tests*)

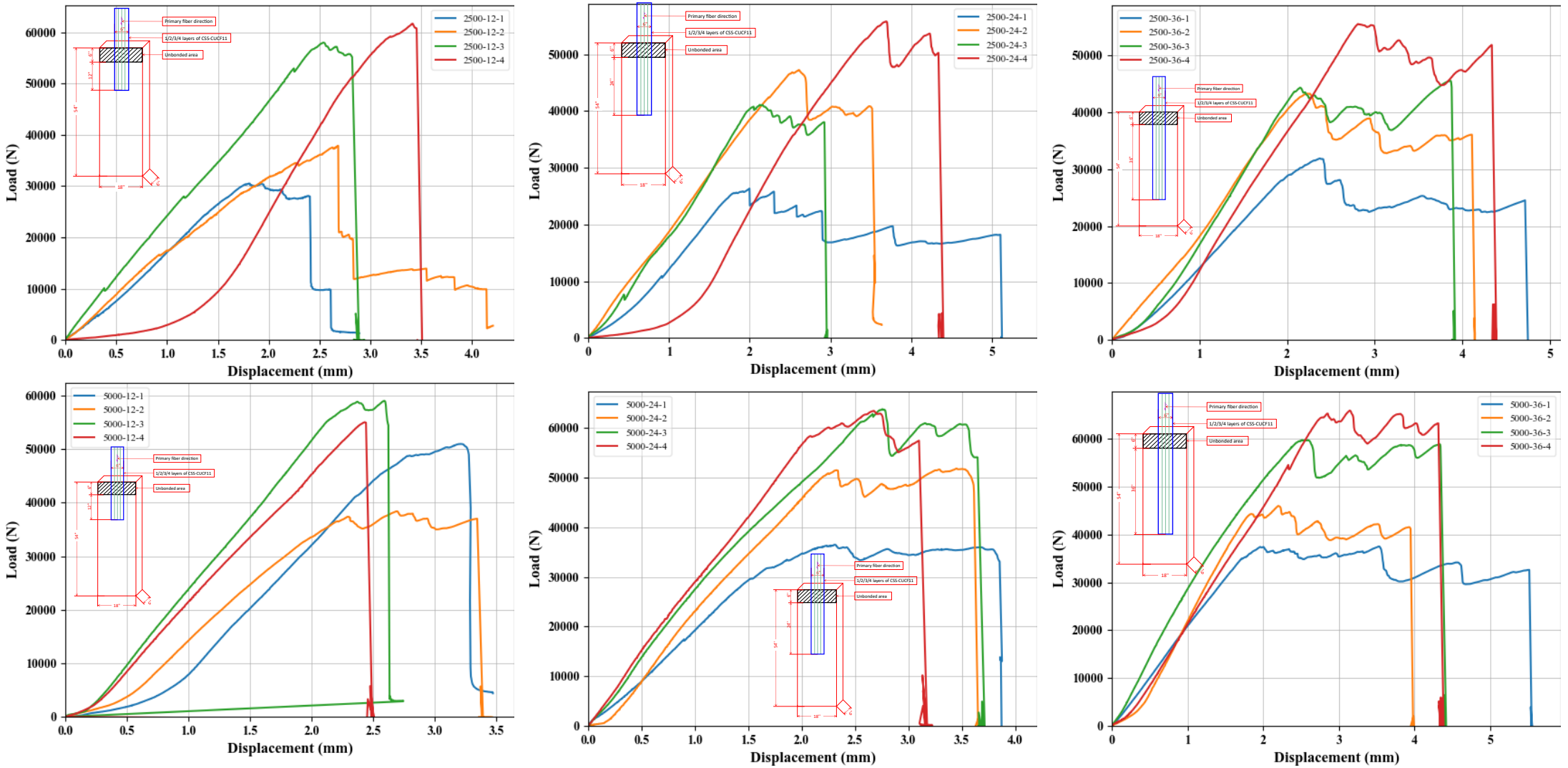


Fig. 10 Load-Displacement curves of 36 unanchored tested

Recent tests *(24 + 36 unanchored tests, Tyrell Gilb Research Lab, Stockton, CA)*

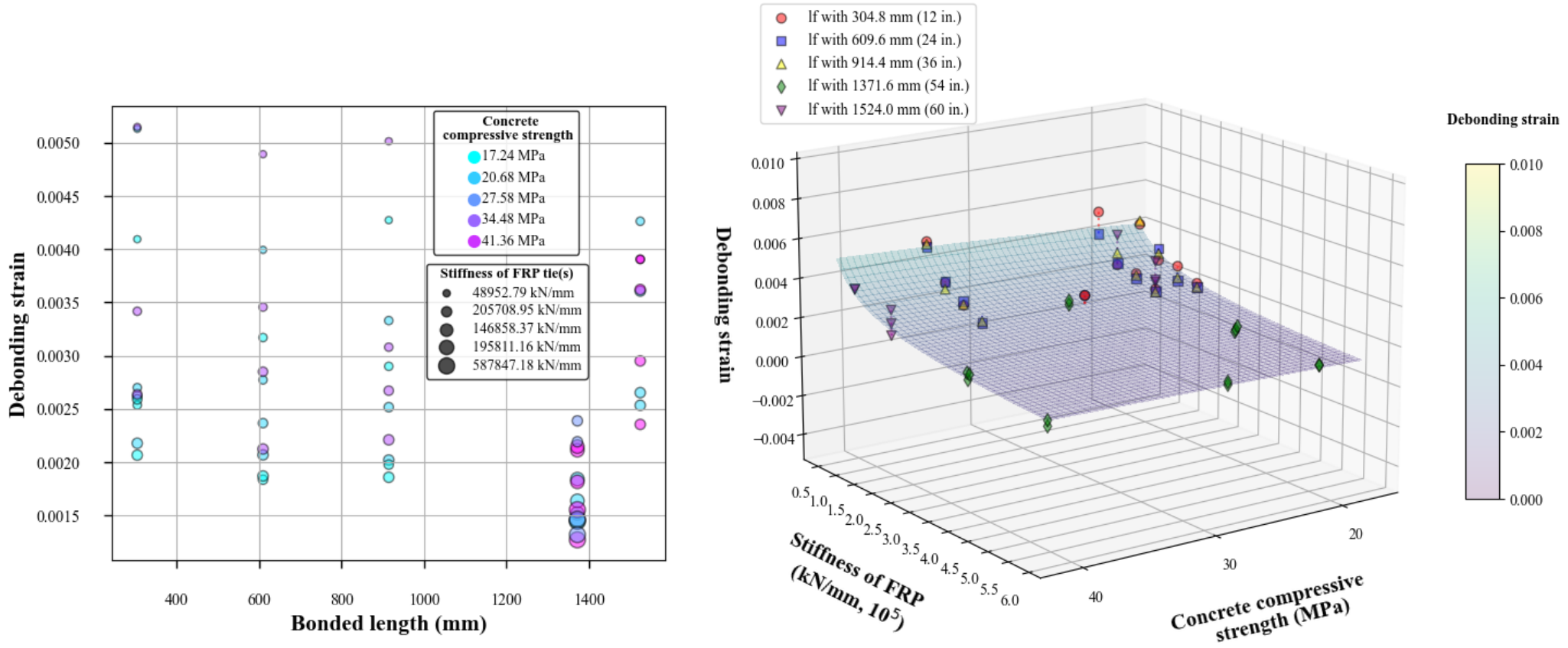


Fig. 16 Test results of 60 unanchored tested in SST

All unanchored tests (*1448+60*)

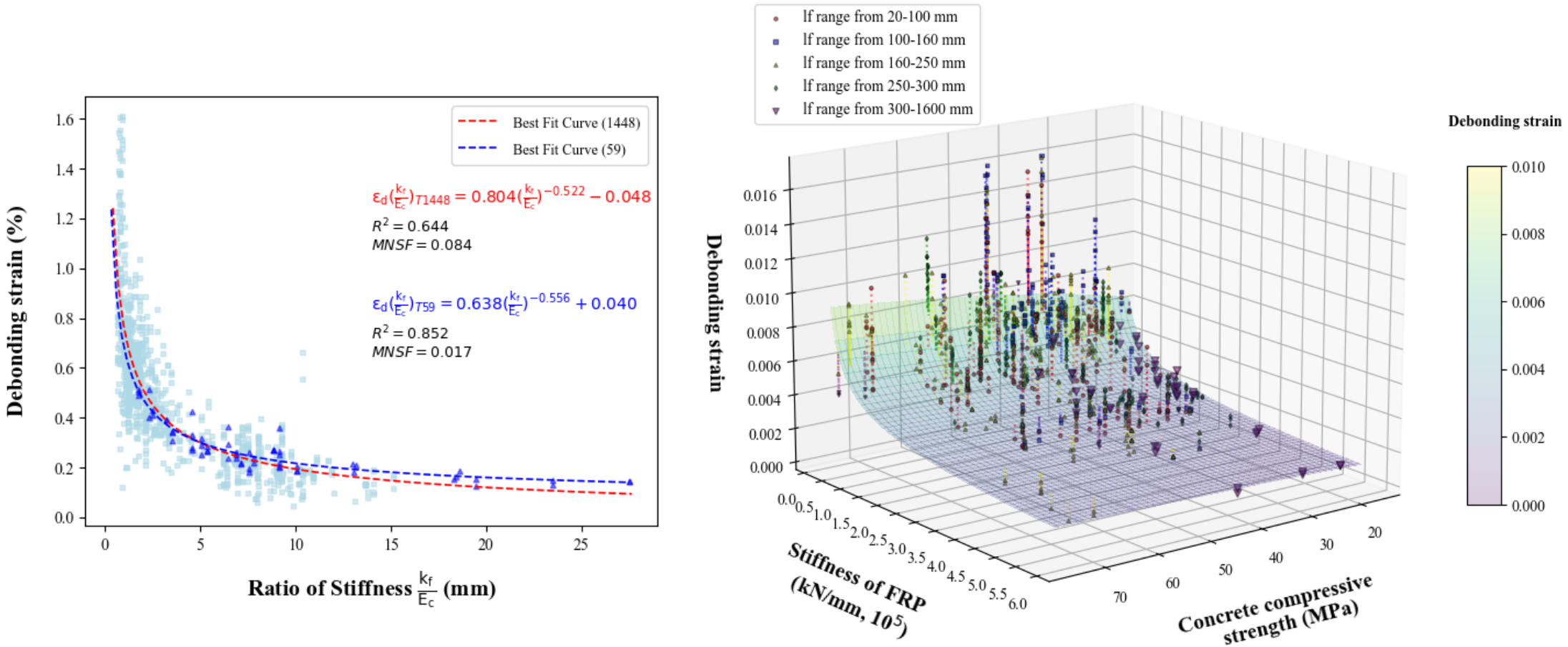


Fig. 17 Updated proposed equation for debonding force (Predicted)

All unanchored tests (*1448+60*)

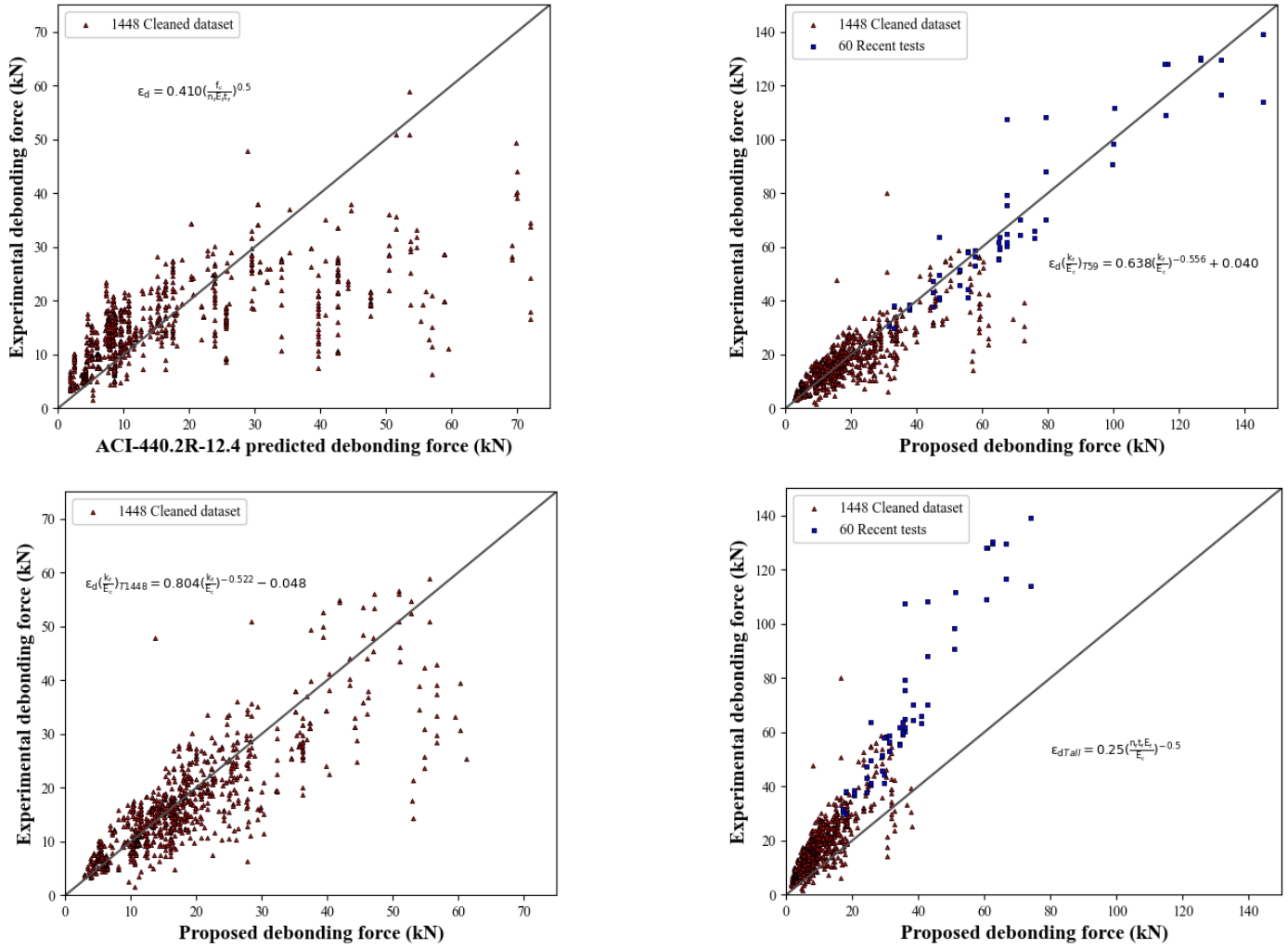


Fig. 17 Updated proposed equation for debonding force (Predict and Design)

Recent tests (*24 anchored tests*)

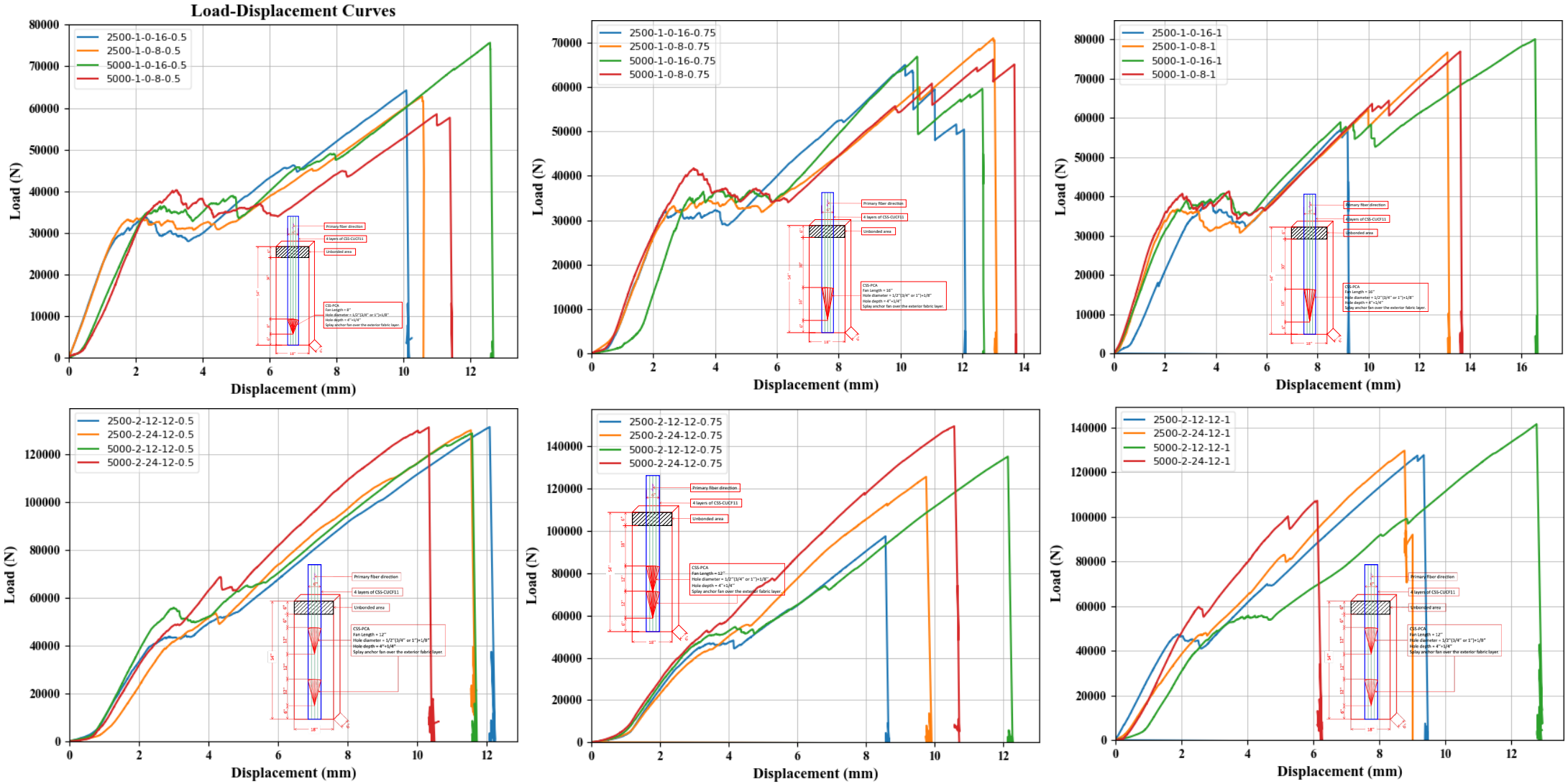
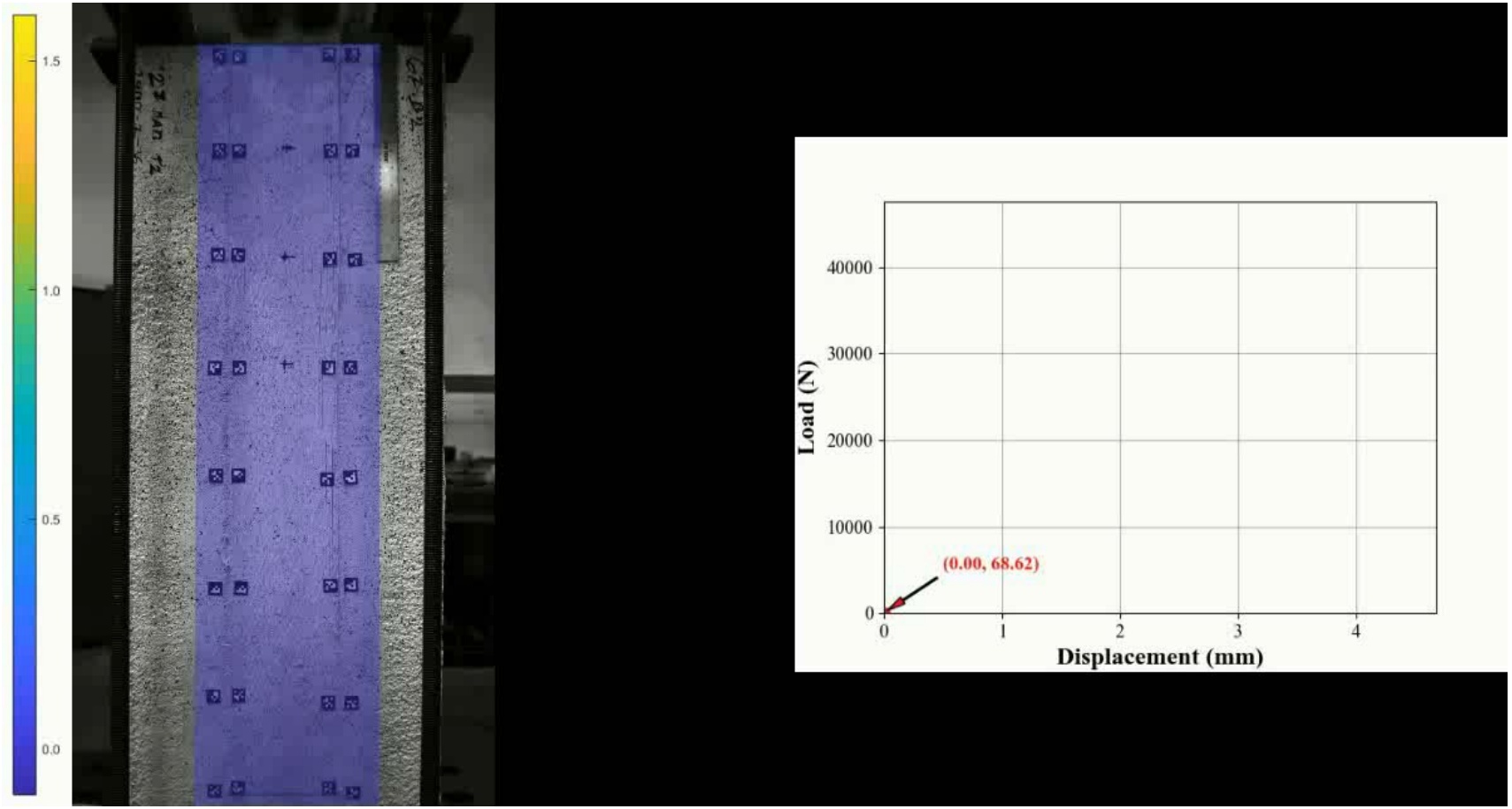


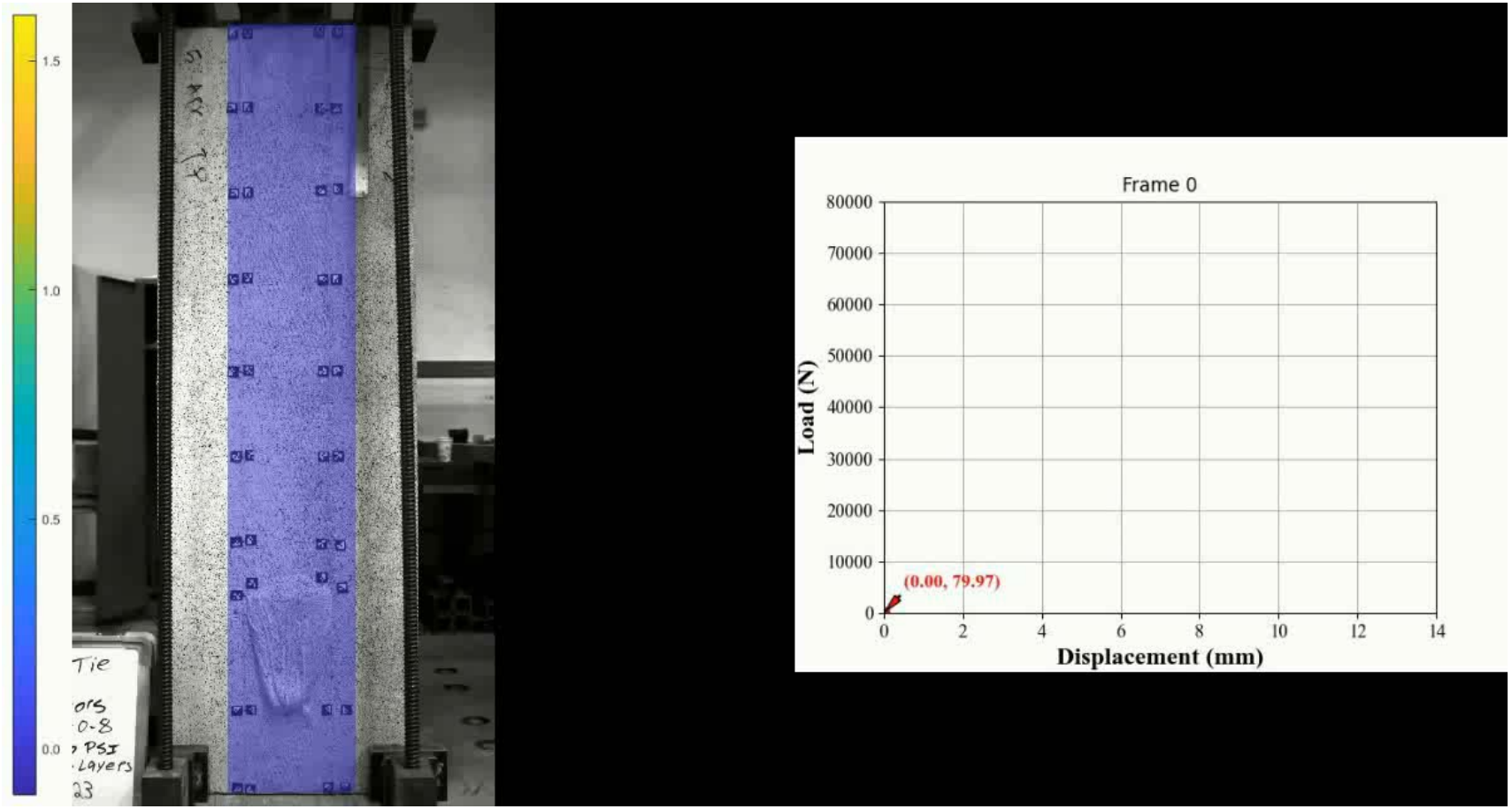
Fig. 19 Overview of database collected (Anchored)

DIC Analysis (*1/36 unanchored tests: specimen 2500-36-2*)



Vid. 8 DIC result and Load-Disp. Curve (2500-36-2)

DIC Analysis (*1/24 anchored tests: specimen 2500-1-0-8-1*)



Vid. 8 DIC result and Load-Disp. Curve (2500-1-0-8-1)

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THANKS
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